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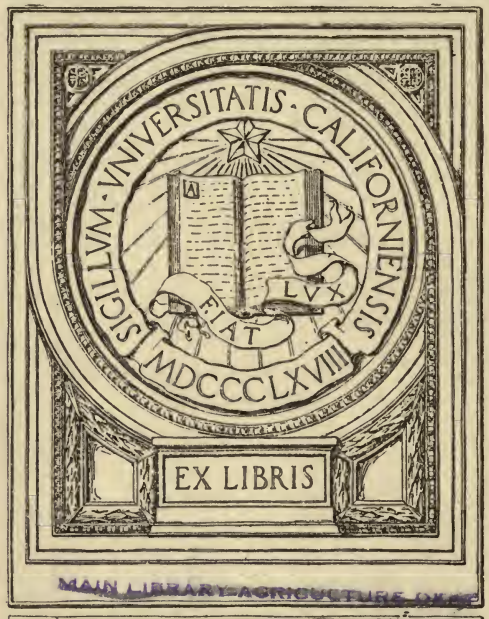

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DEPARTMENT OF AGRICULTURE,
NEW SOUTH WALES.

SCIENCE BULLETIN, No. 12.

October, 1914.

NOTES ON
OSTEO-MALACIA
(Bone-chewing).

Being results of the examination of soils, herbage, &c., from affected areas, carried out in the Laboratory of the Department of Agriculture, New South Wales.

Workers in the respective branches of Economic Science covered by this series of Science Bulletins will receive such of them as may be of use in their special branches of study upon application to the Under Secretary, Department of Agriculture, Sydney.

† 9419

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Introductory.

F. B. GUTHRIE.

THE three papers dealing with osteo-malacia, or bone-chewing, which form the contents of the present Bulletin, embody the work done in the laboratory of the Department in investigating one phase of this disease, namely, the deficiency in certain mineral constituents in the food of animals suffering from the complaint.

The first paper, by Mr. Max Henry, describes the nature and course of the disease, its distribution, and the methods of treatment found to be satisfactory.

Dr. Jensen contributes the results of a fairly exhaustive series of analyses of soils from the South Coast, including those from affected and from unaffected areas, and makes some useful suggestions as to soil treatment, with the object of minimising the prevalence of the disease. The analyses point conclusively to deficiency in mineral plant-food in the soils from the affected areas. In the third paper Mr. A. A. Ramsay gives further results of analyses of these soils with respect to the amounts of lime, potash, and phosphoric acid soluble in water, and with the lime and phosphate contents of the humus matter from the soils of affected and unaffected areas. In this case also the humus from the affected areas was deficient in these ingredients. It was to be expected that the composition of the herbage would be affected by the nature of the soils, and would show a corresponding deficiency in mineral matter. Fairly complete analyses were therefore made of the ash of grasses from affected and unaffected areas, and the lime-magnesia-potash ratio and the lime-potash-phosphoric acid ratio discussed.

Mr. Ramsay adds calculations which show that a cow fed on the grasses growing on the affected areas would get only one half of the mineral matters found necessary to maintain health.

He also adds some analyses of bones taken from cattle suffering from osteo-malacia, which show that they are poorer in ash, notably in lime and phosphoric acid, than bones from healthy cattle from unaffected areas in the same district.

Analyses were also made of the water taken in unaffected and affected areas respectively, but no definite results were obtained, and the analyses are not recorded.

When we add to all the above the undoubted facts, vouched for by Mr. Henry and the officers of the Stock Branch of the Department, that the disease can be cured by removing the stock to areas of richer soil and herbage, or by giving them a lick composed essentially of phosphate of lime, the conclusion is warranted that poverty of the food in mineral ingredients, due primarily to poverty of the soil which supports this herbage, is the predisposing cause in producing bone-chewing amongst cattle in this country.

Diseases of a similar nature amongst stock are met with in other parts of the world, which possess many characteristics in common with the one under discussion. More than one theory has been put forward as to their cause.

In South Africa, for example, a disease known as "Lamziekte," which, though not identical with, possesses many points of similarity to, the local disease, has been made the subject of a considerable amount of investigation, and the predisposing cause has been attributed by some to cumulative vegetable poisoning (Theiler and Robertson), by others to the absence of phospho-proteins (Dr. Juritz), to infection, and to water-borne infection, as well as absence of mineral salts. Another theory is that the disease is analogous to beri-beri, and is caused by the lack of some vitally protective and curative substance (Stead).*

American investigators have also given attention to osteo-malacia. F. H. McCrudden† shows that in the bones of diseased animals the lime is reduced by one-half, and the phosphoric acid by one-third of the quantities present in the bones of healthy animals. This difference is a very much greater one than we have been able to find.

W. Dibbelt‡ has induced artificial osteo-malacia by feeding with certain salts which remove lime from the organism, and has cured the diseases by withdrawing these salts.

G. Moussu,§ dealing with osteo-malacia in pigs, concludes that it is purely an infectious disease. The disease, as described by him, does not appear to be

*_Vide_ Journal of the Department of Agriculture of the Union of South Africa for 1913 and 1914.

†Amer. Journ. Physiology, 1906, vol. xvii, p. 32.

‡Zeitsch: Biochem: Biophys, vol. xii, p. 504.

§Journal d'Agriculture pratique, 1914, Tome 1, No. 13, p. 395.

identical with the local one; notably there is no mention of the bone-chewing propensity which is so marked a feature locally.

The question of the identity or otherwise of the disease in the above-mentioned and similar cases with the osteo-malacia affecting our South Coast cattle is not under discussion in the present Bulletin, which is simply a record of analyses made of soils and herbage found on the areas in which the local disease is prevalent, and of bones of affected animals.

A NOTE ON THE NATURE AND CAUSATION OF OSTEO-MALACIA IN N.S.W.

MAX HENRY, M.R.C.V.S., B.V.Sc., Veterinarian, Stock Branch,
Department of Agriculture.

Osteo-malacia amongst cattle in New South Wales has of late years become rather prominent in certain areas, and some work has been carried out over a rather lengthy period in the way of investigation, principally in the direction of soil analyses. Only lately, however, has the close relationship between the soils and the quality of the grasses grown thereon been shown by the analyses of grasses by the Chemical Branch of the Department of Agriculture, and although the grasses were obtained in connection with other matters, their analyses have thrown much light on the problem of osteo-malacia.

Occurrence.

As was shown in a short note* published previously, osteo-malacia is fairly widely distributed throughout the coastal areas, but this investigation was principally confined to the far South Coast, including the Pastures Protection Districts of Broulee and Eden, the principal centres in each district being respectively Moruya and Bega. Roughly speaking, the disease is becoming more marked as time goes on, but the increase in severity is not constant, as in good seasons it is distinctly milder. In 1907, when the complaint in these areas was first observed by the writer, it was localised on smaller areas than at the present time.

Etiology.

Hutyra and Marek† state that "as in rachitis, so in brittleness of the bones of animals, a deficiency of lime in the organism is undoubtedly of the highest importance," and it would certainly appear that the close correlation of soils deficient in lime and phosphoric acid, as shown by the analyses made by Mr. Guthrie and Dr. Jensen of soils within the affected areas, would fully

* "Osteo-malacia in Cattle in New South Wales" (Henry), *Agricultural Gazette of New South Wales*. Oct., 1912.

† "Special Pathology and Therapeutics of the Domestic Animals."

bear out this contention. At the same time, several contributing causes must be considered in connection with osteo-malacia as found in these areas. Foremost amongst these must be placed the method of dairy-farming adopted. The country, never at any time very rich, has been grazed continuously for generations, and during the greater part of this time by the milk-producing breeds of cattle. Very little feed in the way of crops has been grown on the majority of farms, and even when such crops have been grown no artificial manuring has been, as a rule, resorted to. In short, nothing has been done to replace the food material removed by the cattle.

Again, there is a continued tendency, at all events in the Bega district, to breed with a view to increased milk production only, and since in all cases pregnancy and lactation are recognised as increasing the severity of the complaint, it is likely to be still more noticeable amongst cattle which are simply milk-producing machines.

The investigations so far carried out provide results which are entirely opposed to the theory of the infectious origin of the complaint. Throughout the whole coast of New South Wales, and especially in the areas now being dealt with, the disease is strictly localised, and in between the affected areas are stretches of better country, in which the cattle are never affected, although there is a continuous interchange of cattle between all parts of the district. Very many instances were noted in which cattle from affected herds and affected cattle themselves were removed from affected to non-affected areas without spreading the disease, and, on such removal, those that were affected rapidly recovered.

Symptoms.

As observed in cattle in New South Wales the symptoms follow the classical description very closely. The most marked, and generally the first, sign is a perverted appetite, the cattle seeking out and chewing bones, sticks, shells and other objects, but preferably bones, for which they exhibit an extraordinary craving. The affected animals move stiffly, this stiffness being most noticeable in the hindquarters, and they are often lame. In some instances swellings are noticed at the fetlocks and lower joints of the feet. The back is often arched and the loins sunken. The animal has a general unthrifty appearance, the coat is harsh and dry, and a progressive emaciation is observed. The secretion of milk decreases and finally stops.

Fractures occur readily, especially of the ribs and bones of the limbs, and such fractures heal very imperfectly. The animals finally die from exhaustion.

Course.

The course of the disease is usually chronic, but it is subject to comparatively sudden aggravations during pregnancy and lactation.

Diagnosis.

The disease must be differentiated from another markedly coastal complaint, which, like osteo-malacia, is frequently referred to as "rickets," namely, poisoning by "Burrawang" (*Macrozamia sp.*).

The nature of the country, the presence of the plant, the absence of the "bone-chewing" habit, and the freedom of the animal from fractures will be useful in deciding which complaint is present. Rachitis is excluded by the question of age, as, so long as the calves are on the bucket, *i.e.*, receiving skim-milk, they do not develop osteo-malacia.

Treatment.

As has already been noted, great benefit may be obtained, especially if the animals are noted in the early stages, by removing them to non-affected country. As this is not often practicable, however, recourse must be had to artificial means of supplying the required constituents of the feed, and the course most readily adopted in cases where the cattle are being fed apart from their grazing is to mix 1 to 2 ounces of bone-meal in the feed daily. Where grazing alone is resorted to, the bone-meal may be placed in small boxes, suitably protected from the weather, and the cattle allowed to lick it at will; if salt is also required by the cattle it may be mixed with it, but this is not essential. Bone-meal given in this way has been found of great benefit in many instances.

The addition of bran to the feed has also been noted to act beneficially, and much good has resulted on other occasions by partly feeding on maize or lucerne or oaten hay grown outside the affected areas.

Preventive treatment can only lie in the direction of providing more artificial feed for the cattle, by growing crops with the use of artificial manures, and where possible liming and manuring the pastures, though, as Dr. Jensen points out, the last measure is sometimes superfluous.

THE OSTEO-MALACIA SOILS OF THE SOUTH COAST DISTRICTS.

H. I. JENSEN, D.Sc., Government Geologist, Northern Territory; late of the Chemist's Branch, Department of Agriculture, N.S.W.

On the South Coast osteo-malacia is very prevalent in many localities, as at Sassafras and in various parts of the Moruya and Bega districts. It is generally most acute where the soils exhibit a marked deficiency in lime, and when one portion of a district is affected and another unaffected, a notable difference usually exists in the lime content of the soils of the two localities.

For a considerable time the matter has been under investigation in this Branch, and upwards of sixty soils have been analysed in connection with the bone-chewing disease, or osteo-malacia. Prior to this investigation

several "bone-chewing" soils had been analysed by Mr. F. B. Guthrie, with the result that he came to the conclusion that the complaint was due in the main to a deficiency of lime and phosphates in the soil. Accordingly a lick was prescribed, consisting of bone-ash, salt, ferrous sulphate and molasses, which has proved effective in checking the complaint. The liming of the worst affected paddocks has also been tried with success.

The present more exhaustive investigation of soils from the affected and unaffected areas fully bears out the conclusions already arrived at by Mr. Guthrie.

The unaffected areas consist mostly of dark-coloured soils, well supplied with lime and possessing a porous subsoil. The affected areas have light-coloured, poor soils, and clayey subsoil. In connection with this the writer has noticed in various parts of the States of New South Wales and Queensland that the bone-chewing habit is always most prevalent on geological formations like sandstones, aplites and granites, which yield silicious sandy soils, poor in lime, and is absent on limestone, basalt, dolerite, diorite and gabbro soils which are well supplied with lime. The following facts, however, tend to render difficult the solution of the problem, and the cause of the complaint:—

(*a*) For a large number of years the Moruya and Bega districts, with their granitic soils, were free from the disease, but of late years it has become rampant in parts;

(*b*) Some of the affected areas in these districts have better soils than unaffected areas in other districts;

(*c*) The Bergalia Andesite soil from an infested paddock is comparatively rich in lime and phosphoric acid.

How far the exhaustion of the cows by dairying in districts where formerly breeding for the market was the industry, and how far the artificial feeding of calves has created a tendency to disease, are matters for others to discuss, but the soil itself in those affected areas which are not excessively deficient in lime often shows certain peculiarities that deserve special mention.

The surface 4 inches of soil in bone-chewing areas is often exceedingly hard, almost as hard as cement, so that a pick must be used to break it up. The subsoil is also rather hard, lumpy and dry. The causes of these peculiarities are probably, first, the clearing or ringbarking of the country, and, secondly, the continued tramping of cattle on the ground.

Clearing or ringbarking has the effect of destroying the life of those large tree-roots whose growth causes constant breaking up and aeration of the subsoil. The humus percentage of the surface soil, which, in the natural state, keeps it in a loose and aerated condition, is greatly reduced by the absence of decaying leaves and grass; for the trees are now gone, and no longer yield the former, and the grass is eaten by the cattle as fast as it grows. Absence of vegetable matter and the constant trampling leads to the surface soil forming a hard crust, which is probably further cemented by salts drawn up from below by capillarity.

The absence of vegetable matter hinders the transformation of the lime silicates and zeolites into carbonate, in which form the lime is most beneficial. The hardness of the surface soil prevents water and air from reaching the subsoil, hence that animal life—particularly earth-worms—which should exist in the soil to maintain its fertility, is absent. The lime is therefore not brought up to the surface by these animal agencies. As a result, only the hardiest and coarsest grasses will grow. This probably accounts for the rapid spread of Bergalia grass in the South Coast districts in recent years.

It appears, therefore, that this land suffers from a kind of exhaustion brought on by clearing and overstocking, without any effort to maintain the condition of the soil.

To give each paddock in turn a complete rest for a year or two would probably be beneficial, inasmuch as it would restore some vegetable matter to the surface soil. It would be still better to break up the surface prior to giving the land a rest. It is clear from the analyses that the lime is never completely exhausted, but it must be in a form little suited for the needs of the grass.

The addition of lime to the soil has, according to Inspector Furness, proved of benefit both to the grass and to the cattle wherever experimentally tried; but in some cases, as for instance on the Bergalia andesite, it is like "carrying coals to Newcastle," the lime being there, if only the land-owner will give it a chance to become available.

In the writer's opinion, to rest and aerate the paddocks will, in certain cases, as at Bergalia, do far more good than to spread lime on the surface, and to give licks to the cattle. This is the way to get back the good grasses and heavyweight cattle of former years, now fast disappearing. Each paddock in its turn should be rested and broken up, to restore its fertility. Overstocking year after year should be avoided, since the eating off of the grass prevents that return of vegetable matter (humus) to the soil which is desirable, and exposes the soil to the extreme burning rays of the sun and the patter of the rain.

Tables Ia and Ib give the analyses of soils from affected and unaffected areas respectively in the Bega district, which were sent by Stock-Inspector C. O. Furness, through the Stock Branch, for investigation. The difference in lime and phosphoric acid is very striking. The lime content of the osteo-malacia soils is invariably less than ·275 per cent., and that of the "unaffected" soils greater than ·300 per cent. The phosphoric acid of the affected areas is always less than ·125 per cent., and that of the free areas greater than ·125, except in one instance. The volatile matter of the unaffected areas is double that of the affected. The nitrogen and humus percentages are also much lower in the osteo-malacia localities than in places where the disease does not occur. Magnesia varies pretty constantly with the lime. Other oxides of metals exhibit the same striking variation.

The subsoil of the affected areas is typically a hard, gravelly clay, which is very low in oxides of lime, magnesia, and iron; it consists chiefly of very fine quartz and felspar, very little of which is sufficiently decomposed to be acid-soluble.

The subsoil of the unaffected areas is a gravelly or sandy loam, rich in oxides of bases, both in acid-soluble and insoluble form.

Table II gives a comparison between the average compositions of seventeen soils from affected parts of the South Coast and seventeen soils from unaffected parts. As the analyses have already appeared in my paper on "The South Coast Soils,"* they are not again published. The facts noticed in comparing Tables Ia and Ib are again in evidence, and come out still more strikingly if we compare five typical osteo-malacia soils, on which the *disease* is *rampant,* with seventeen soils from *absolutely free* areas, as in Tables III and IV.

Through the kindness of Stock-Inspector Mater I was supplied with some more Bergalia andesite soil, on which bone-chewing was very bad, and I found these samples of even better chemical composition than the one previously examined. Moreover, there is no diminution of lime upwards, the first 4 inches being as rich in that ingredient as the third 4 inches. In the course of the analyses it was, however, discovered that the top soil contains a large amount of manganese, which is less plentiful at a depth. The average manganese percentage in the first 12 inches is ·140 per cent., so the surface 4 inches may contain ·250 per cent. This being quite sufficient to injure most of the nutritious grasses, the presence of manganese in such amount may therefore be the cause of the spread of Bergalia grass, and thus, indirectly, of the bone-chewing habit.

It is clear from the analyses that when lime falls below ·250 per cent. the soil has no lasting qualities, and the cattle on it become bone-chewers. A few years of cultivation and dairying exhausts such soil.

* *Agricultural Gazette of New South Wales*, vol. 21, p. 95 (February 1910)

TABLE Ia.—Osteo-malacia Soils, Bega District, Granitic Formations.

Locality.	Colour.	Reaction.	Water Capacity.	Capillary Power.	Clay.	Volatile.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.	Magnesia	Humus.	Iron and Aluminium Sesquioxides.
			per cent.	inches.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Warragaburra	Dark ...	Acid	36	6½	29·9	7·57	·168	·271	·122	·109	n d.	2·130	...
Ayrdale, No. 2	Light ...	Acid	35½	6	34·5	8·20	·154	·225	·023	·070	...	1·633	...
Schuebach's	Light ...	Acid	23	3¾	44·5	5·52	·126	·118	·101	·070	...	1·994	...
Bemboka	Light ...	Strongly acid	34	6	...	4·68	...	·128	·080	·072	·131	...	1·03
Coolagalite	Light ...	Strongly acid	...	...	...	6 51	...	·100	·038	·049	...	...	...
Verona	Light ...	Acid	...	...	...	5·75	...	·194	·060	·030	·101	...	1·00
Narara	Light ...	Strongly acid	...	...	...	5·13	...	·146	·071	·060	...	...	...
Mogilla	Light ...	Strongly acid	...	...	...	4·13	...	·043	0·50	·038	·036	...	1·41
*Subsoil, Bemboka ...	White ...	Acid	...	5	...	2·42	...	·075	0·42	·020	·049	...	0·72
Average of surface soils	...	...	low 33½	good 5½	36·3	5·94	·149	satisfactory ·155	fair ·072	fair ·057	fair ·080	1·917	1·04

* A fusion of this subsoil gave on analysis: Silica (SiO_2), 77·40 per cent.; iron oxide (Fe_2O_3), 2·14 per cent.; alumina, (Al_2O_3), 10·54 per cent.; lime (CaO), ·58 per cent.; magnesia (MgO), ·20 per cent.; loss on ignition, 2·42 per cent.; undetermined, including alkalies, 6·72 per cent.

TABLE Ib.—Non-affected Soils, Bega District, Granitic Formations.

Locality.	Colour.	Reaction.	Water Capacity.	Capillary Power.	Clay.	Volatile.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.	Magnesia.	Humus.	Iron and Aluminium Sesquioxides.
			per cent.	inches.	per cent	per cent	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Ayrdale Peak	Almost black	Acid	36½	8	34·9	10·98	·364	·616	·417	·152	...	2 296	...
Numbugga	Dark ..	Acid	34	5	36·2	9·86	·233	·566	·341	·157	...	3·103	...
Daisy Bank	Dark ...	Acid	41½	8	30·0	8·40	·196	·340	·314	·140	...	3·039	...
Meringlo	Brown ...	Acid	...	...	...	8·06	...	·401	·104	·058	·348	...	Fe_2O_3, 3·75 Al_2O_3, 2·59
Brogo	Brown ...	Strongly acid	...	7	...	10·75	...	·443	·236	·129	·371	...	Fe_2O_3, 2·25 Al_2O_3, 4·15
*Subsoil, Brogo	Brown ...	Acid	...	10	...	9·37	...	·806	·109	·056	1·040	...	Fe_2O_3, 6·75 Al_2O_3, 12·68
Average of Surface Soils.	...	...	fair 37	very good 7	33·7	9·61	·266	good ·473	good ·282	satisfactory ·127	good ·359	2·814	

* A fusion of this subsoil yielded on complete analysis: Silica (SiO_2), 56·86; alumina (Al_2O_3), 18·22; ferric oxide (Fe_2O_3), 9·00; Lime (CaO), 2·25; magnesia (MgO), 1·70; loss on ignition, 9·37; undetermined, including alkalies, 2·60.

TABLE II.—Comparison of Affected and Unaffected Areas.

	Colour.	Reaction.	Capillary Power.	Water Capacity.	Clay.	Moisture.	Volatile.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.	Geological Formation.
			inches.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	
Average of 17 soils from Affected Areas, South Coast.	Mostly light	Usually strongly acid.	Good to very good	fair 36	43·2	2·47	6·90	good ·157	satisfactory ·168	fair ·087	indifferent ·047	Granite, sandstone, aplite, schist, and phyllite.
Average of 17 soils from Unaffected Areas, South Coast.	Mostly dark	Neutral to acid.	Good to very good	fair 43	58·0	4·40	12·02	good ·282	good ·465	satisfactory ·143	satisfactory ·184	Diorite, granite, basalt, and alluvial.
Average of 5 Typical Osteo-malacia Soils, given in Table III.	Light.	Very strongly acid.	fair 5	low 30	40·8	2·80	5·78	good ·151	fair ·076	fair ·073	satisfactory ·035	Granite, sandstone, aplite, and phyllite.
Average of 7 Typical Unaffected Soils, given in Table IV.	Dark.	Faintly acid.	good 6.6	fair 43	55·6	4·61	13·84	good ·343	very good ·623	satisfactory ·199	good .245	Diorite, granite, basalt, and alluvial.

TABLE III.—Type Soils, Affected Areas.

SOUTH COAST.

Locality.	Geological Formation.	Colour.	Reaction.	Capillary Power.	Water Capacity.	Clay.	Moisture.	Volatile.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.
				inches.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Sassafras	Sandstone ...	Grey... ...	Very strongly acid	4·1	12	28·6	5·11	4·46	·098	·010	·050	·029
Turpentine	Shaley sandstone	Grey... ...	Strongly acid ...	4	39	52·8	3·70	6·42	·147	·055	·057	·036
Flat Cobargo	Granite	Light Grey...	Strongly acid ...	7	35	40·6	1·45	4·14	·083	·060	·027	·035
Nogooroola	Granite	Grey... ...	Strongly acid ...	6	32	42·7	1·56	5·75	·224	·164	·059	·033
Nelligen	Schist	Light Grey..	Strongly acid ...	5	31	39·3	2·17	8·13	·203	·092	·104	·040

For Averages, see Table II.

TABLE IV.—Type Soils, Unaffected Areas.

Locality.	Geological Formation.	Colour.	Reaction.	Capillary Power.	Water Capacity.	Clay.	Moisture.	Volatile.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.
Shoalhaven Flats ...	Alluvial	Dark grey ...	Faintly acid ...	inches. 7·2	per cent. 40	per cent. 71·9	per cent. 3·84	per cent. 8·82	per cent. ·294	per cent. ·255	per cent. ·110	per cent. ·189
Milton	Diorite	Reddish ...	Acid	7	47	44·0	5·05	12·81	·350	·382	·090	·078
Tilba	Diorite	Brown black	Neutral	8	49	64·0	4·06	11·51	·280	·916	·099	·379
Brogo	Diorite	Dark brown	Acid	7	41½	49·5	3·35	12·55	·252	·930	·185	·128
Kiama	Bombo basalt ...	Chocolate ...	Acid	6	35	68·0	8·30	24·65	·651	·662	·234	·674
Buckembowra	Granite	Brownish ..	Acid	6	42	12·0	2·29	8·75	·252	·536	·462	·096
Keira	Mudstone ...	Light brown	Acid	5	48	79·7	5·38	14·43	·322	·582	·213	·232

For averages, see Table II.

INVESTIGATIONS UNDERTAKEN IN CONNECTION WITH "OSTEO-MALACIA" or "BONE-CHEWING DISEASE" ON THE SOUTH COAST.

A. A. RAMSAY, Chief Assistant, Chemists' Branch.

Investigations into the cause of Osteo-malacia (also known as "Bone-chewing," "Rickets," and "Stiffs") were commenced in 1908, and have been carried on as time permitted up to the present time. The area dealt with was the South Coast district, where the disease was particularly manifest. These investigations were conducted on—

(*a*) The composition of soils from affected and non-affected areas.

(*b*) The composition of the grasses from affected and non-affected areas.

(*c*) The composition of bones of animals reared on affected and non-affected areas.

Soils.

The composition of seventeen samples of soil from affected and seventeen from unaffected areas is set forth in Table II of Dr. Jensen's paper. It will be noticed that the difference is most marked. This is particularly so in the fertilising ingredients, nitrogen, potash, lime, and phosphoric acid; the soils from the affected areas containing very much less of these than do the soils from the non-affected areas. This difference is also shown in the water-soluble lime, phosphoric acid, and potash, as shown in Table V, the quantities of lime and potash being less in the soils from the affected areas than in those from the non-affected areas.

Another striking point of interest between these two classes of soils is in the quantity of phosphoric acid and lime in the humus from affected and non-affected areas. This is shown in Table VI. It is seen that again the quantity of lime and phosphoric acid is less in the humus in the affected soils than in that from the non-affected soils.

We have therefore established the fact that soils from the affected areas contain less fertilising ingredients, namely, nitrogen, lime, potash, and phosphoric acid, than do those from the non-affected areas, and are, in consequence, likely to produce a less nutritious herbage.

Soils from Affected and Unaffected Areas (South Coast).

TABLE V.

Water-soluble lime, potash, and phosphoric acid.

	Average in Soils from Affected Area.	Average in Soils from Non-affected Area.
	Parts per million.	Parts per million.
Lime (CaO)	30·0	37·0
Phosphoric Acid (P_2O_5)	4·3	4·0
Potash (K_2O)	82·7	101·0

TABLE VI.

COMPOSITION of the Humus from Affected and Non-affected Areas.

	Affected Area.	Non-affected Area.
	per cent.	per cent.
Lime (CaO) in Humus	·018	·094
Phosphoric Acid (P_2O_5) in Humus	·031	·050

Grasses.

At the beginning of these investigations three samples of grass from affected areas and three from unaffected areas were received from the Stock Inspector, who stated in his covering letter, "Owing to the scarcity of herbage here at present I am unable to send you anything like a fair sample of grass, having to cut under the soil to obtain any at all." Since these were the only samples available for this work, an analysis of them was accordingly made. These are set forth in Table VII (A and A1), the former being from affected areas and the latter from unaffected areas. Later on in the season five further samples of grass, identified by the Government Botanist as *Eragrostis leptostachya,* a common grass in New South Wales from the coast districts to the tablelands, were received, all from affected areas. The composition of the ash of these is set forth in Table VII (A2).

The mean of all these grasses from affected and non-affected areas is given in Table VII (B).

From these figures it is seen that the ash of the grass from affected areas contains very much less phosphoric acid and lime than does the ash of grass from non-affected areas.

TABLE VII.

COMPOSITION of Grasses from the South Coast from Affected and Non-affected Areas.

		Total Ash in Dry Matter, &c.	Percentage Composition of Ash.	
			Phosphoric Acid.	Lime.
		per cent.	per cent.	per cent.
A	Mean of 3 grasses from affected areas	11·75	0·38	5·51
A1	Mean of 3 grasses from non-affected areas ...	9·93	2·76	9·11
A2	Mean of 5 grasses from affected areas	8·68	1·34	1·62
B	Mean of the above grasses from affected areas ...	9·83	0·98	3·08
	Mean of the above grasses from non-affected areas	9·93	2·76	9·11

Of couch grass and prairie grass, two of the most ideal feeds for cattle, about half a hundredweight is required to supply the necessary protein and starch, and this amount may be taken as the quantity of grass eaten by an average cow per day.

Stohmann has found that a cow of 1,000 lb. live weight requires 1·4 oz. phosphoric acid, 2·1 oz. lime, and 3·8 oz. potash per day.

Applying the data mentioned to the above grasses from affected and unaffected areas, and assuming the grass as eaten to have the same moisture content as ordinary grass, namely, about 70 per cent. of moisture, it is to be

noted that the cow fed on the grass from the affected areas would only be receiving ·26 oz. phosphoric acid and ·81 of lime, and if fed on the grass from non-affected areas, the cow would receive ·74 oz. phosphoric acid and 2·43 oz. lime, and the minima necessary to health, according to Stohmann, are 1·4 oz. phosphoric acid and 2·1 oz. lime.

Further opportunity of examining grasses from affected and non-affected areas did not occur till later, when six samples of herbage were received, four from badly affected areas and two from non-affected areas. These were collected by an officer of the Stock Branch and forwarded for examination, marked A1, A2, B1, B2, C1, C2.

These were submitted to the Government Botanist, who reports as follows:—

A1.—Under this number there are three species of grasses, namely, *Festuca bromoides, F. ciliata, and Eragrostis.* The latter is too imperfect to work out the species.

A2.—This contains *Festuca bromoides* and a tuft of *Andropogon sp.* without flowers.

B1.—*Sorghum plumosum, Festuca bromoides,* and a tuft without flowers.

B2.—*Festuca ciliata, Poa cæspitosa,* and tufts of another species without flowers.

C1.—*Festuca myurus, F. ciliata, Bromus mollis, Poa cæspitosa,* and tufts of a species without flowers.

C2.—*Festuca myurus, F. ciliata,* and *Poa cæspitosa.*

The samples were submitted to the Biological Branch for examination for fungi. The report furnished is as follows:—

A1.—*Ascochyta*-like spores present.

A2.—A few smut spores present.

B1.—A little smut present on one inflorescence. *Fusarium sp.* present.

B2.—*Septoria sp.* present.

C1.—*Septoria sp.* present, *Fusarium sp.* present, *Ascochyta sp.* present.

C2.—Spores present, probably those of *Sphaeropsis* and *Fusarium.*

"No fungus parasite was found to be constantly present, and the fungi detected were, for the most part, saprophytic, and such as one might expect to find on almost any pasture."

The localities from which these samples of grass were obtained are given in the letter of submittal as follows:—

A1.—Sample from badly affected country near Bega, following Black Range (Gowing, Rodgers, Schuback Bros.).

A2.—Sample from near Wolumla, very badly affected (Sweeney's to Black's "Ayrdale," including Reids and Ryans).

B1.—Taken from Green Brothers, near Bemboka, badly affected.

B2.—Taken from Pollock's Flat, Bemboka, very badly affected.

C1.—Taken from Meringlo and Numbugga, unaffected country; some of the best lands recovered from rabbits.

C2.—Taken from the Peak country near Bega, unaffected land; more or less affected with rabbits, and yielding a smaller variety of grasses.

A more exhaustive chemical analysis was made of these grasses than was previously done. The methods adopted were those of the Association of Official Agricultural Chemists of America.*

Ash was determined by burning in carbonic acid gas and oxygen.

TABLE VIII.

ANALYSES of Grasses from Affected and Unaffected Areas.

	A1 (affected), near Bega.	A2 (affected), Wolumla District.	B1 (affected), Bemboka District.	B2 (affected), Bemboka District.	C1 (unaffected), Meringlo and Numbugga.	C2 (unaffected,) Peak country near Bega.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Moisture	9·44	9·11	9·43	9·68	9·91	9·59
Volatile and organic matter	84·15	77·89	79·95	79·50	79·19	81·04
Ash	6·41	13·00	10·62	10·82	10·90	9·37
	100·00	100·00	100·00	100·00	100·00	100·00
Analysis of Ash :—						
Silica	3·97	10·55	8·03	8·06	7·37	5·55
Phosphoric acid ...	·27	·24	·30	·30	·56	·56
Lime	·33	·34	·42	·44	·41	·42
Magnesia	·15	·15	·17	·17	·21	·19
Potash	1·02	·72	·93	1·05	1·48	1·53
Not determined ...	·67	1·00	·77	·80	·89	1·12
	6·41	13·00	10·62	10·82	10·90	9·37

TABLE IX.

ANALYSES of the above Grasses calculated to a 70 per cent. moisture basis.

	A1 (affected).	A2 (affected).	B1 (affected).	B2 (affected).	C1 (unaffected).	C2 (unaffected).
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Moisture	70·00	70·00	70·00	70·00	70·00	70·00
Volatile and organic matter	27·88	25·71	26·48	26·41	26·37	26·89
Ash	2·12	4·29	3·52	3·59	3·63	3·11
	100·00	100·00	100·00	100·00	100·00	100·00
Silica	1·31	3·48	2·66	2·68	2·45	1·84
Phosphoric acid ...	·09	·08	·10	·10	·19	·19
Lime	·11	·11	·14	·15	·13	·14
Magnesia	·05	·05	·06	·05	·07	·06
Potash	·34	·24	·31	·35	·49	·51
Not determined ...	·22	·33	·25	·26	·30	·37
	2·12	4·29	3·52	3·59	3·63	3·11

* *Bulletin* 107 revised, U.S. Dep. Agriculture, Bureau of Chemistry, page 236, and 22.

TABLE X.

ANALYSES of Grass from Affected and Unaffected Areas.

Calculated to dry substance.

	A1 (affected).	A2 (affected).	B1 (affected).	B2 (affected).	C1 (unaffected).	C2 (unaffected).
Volatile and organic matter.	per cent. 92·92	per cent. 85·70	per cent. 88·27	per cent. 88·02	per cent. 87·90	per cent. 89·64
Ash	7·08	14·30	11·73	11·98	12·10	10·36
	100·00	100·00	100·00	100·00	100·00	100·00
Silica	4·38	11·61	8·87	8·92	8·16	6·14
Phosphoric acid ...	·30	·26	·33	·33	·62	·62
Lime	·36	·37	·46	·49	·46	·46
Magnesia	·17	·17	·19	·19	·23	·21
Potash	1·13	·79	1·03	1·16	1·64	1·69
Not determined ...	·74	1·10	·85	·89	·99	1·24
	7·08	14·30	11·73	11·98	12·10	10·36

TABLE XI.

PERCENTAGE composition of the Ash.

	A1 (affected).	A2 (affected).	B1 (affected).	B2 (affected).	C1 (unaffected).	C2 (unaffected).
Silica	per cent. 61·96	per cent. 81·14	per cent. 75·61	per cent. 74·45	per cent. 67·47	per cent. 59·22
Phosphoric acid ...	4·17	1·88	2·79	2·80	5·11	6·01
Lime	5·17	2·58	4·00	4·05	3·73	4·50
Magnesia	2·36	1·19	1·59	1·58	1·90	2·01
Potash	15·85	5·54	8·71	9·73	13·62	16·36
Not determined ...	10·49	7·67	7·30	7·39	8·17	11·90
	100·00	100·00	100·00	100·00	100·00	100·00
Lime-Magnesia ratio.	1: 0·46	1: 0·46	1: 0·40	1: 0·39	1: 0·51	1: 0·45
Lime-Magnesia-Potash ratio.	1:0·46:3·07	1:0·46:2·15	1:0·40:2·18	1:0·39:2·40	1:0·51:3·65	1:0·45:3·64

Lime-Magnesia-Potash ratio { Average from affected areas ... ... 1 : 0·43 : 2·45
,, from unaffected areas ... ... 1 : 0·48 : 3·65

TABLE XII.

ASH analyses of German and American Grasses.

	Ash in dry matter.	Percentage composition of the Ash.				
		Silica.	Phosphoric acid.	Lime.	Magnesia.	Potash.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
German Grasses—by E. VON WOLFF						
Lime-Magnesia-Potash, 1: 0·43 : 3·56	7·44	28·27	9·39	9·59	4·08	34·18
American Grasses—by C. RICHARDSON						
Lime-Magnesia-Potash, 1 : 0·58 : 3·53	7·97	38·74	6·11	7·25	4·22	25·57

Lime, magnesia and phosphoric acid were determined in the ash obtained by carefully igniting the grass at a low temperature, and potash was determined in the ash obtained by first sulphating the grass and then igniting at a low temperature.

The results of the analysis of the grass as received is given in Table VIII, and in Table IX is given those analyses calculated to 70 per cent. moisture content, which is the percentage of moisture in average grass.

In Table X these have been calculated to a moisture-free basis, and the ash constituents have been stated in percentage of the total ash in Table XI. This has been done to enable these to be readily compared with published analyses from other sources. The ratio of lime to magnesia to potash is also to be found at the foot of Table XI.

For purposes of comparison the composition of the ash of grasses grown in other countries is given, and also the lime-magnesia-potash ratio (Table XII).

On referring to Table XI it is to be noted that in grass from affected areas the lime-magnesia-potash ratio (1:0·43:2·45) is lower than that from non-affected areas (1:0·48:3·65), and also that the latter more nearly approaches the mean lime-magnesia-potash ratio of German and American grasses (1:0·51:3·55), while the former is decidedly under the mean.

This difference in lime, potash, and phosphoric acid between grass from affected and non-affected areas is possibly rendered more apparent if we consider the amounts of these substances that an ordinary cow would ingest if she were to eat an ordinary daily ration of these grasses. To illustrate this, Table XIII has been prepared, which shows the number of ounces of mineral matter that the cow would obtain were it to consume 56 lb. weight of grass, which is considered to be a good average quantity.

Table XIII shows very clearly that if the ordinary ration of grass is fed to a cow (viz., 56 lb.), it is only in samples C1 and C2 (from unaffected areas) that the amounts of mineral matter, 1·66 and 1·67 oz. phosphoric acid, 1·21 and 1·25 oz. of lime, 4·42 and 4·56 oz. of potash, approximates the amounts of these ingredients found by Stohmann to be necessary to health. In all the other cases these amounts are only about half of the mineral matter found to be necessary.

The investigation seems to indicate that it is the absolute shortage in lime, potash, and phosphoric acid to the cow which causes areas A1, A2, B1, and B2 to induce bone-chewing, and explains the absence of the disease on areas represented by C1 and C2.

TABLE XIII.

ASSUMING that 56 lb. of the grasses from Bega district are fed to cows, the animals would receive the undermentioned amounts of mineral matter:—

Mineral matter necessary according to Stohmann.	—	A1 (affected)	A2 (affected)	B1 (affected)	B2 (affected)	C1 (unaffected)	C2 (unaffected)
		lb.	lb.	lb.	lb.	lb.	lb.
	Moisture	39·20	39·20	39·20	39·20	39·20	39·20
	Volatile & organic matter	15·61	14·40	14·83	14·79	14·77	15·06
	Ash	1·19	2·40	1·97	2·01	2·03	1·74
		56·00	56·00	56·00	56·00	56·00	56·00
		oz.	oz.	oz.	oz.	oz.	oz.
	Silica	11·80	31·16	23·83	23·94	21·92	16·49
1·4	Phosphoric Acid ...	·78	·72	·88	·90	1·66	1·67
2·1	Lime	·99	·99	1·26	1·30	1·21	1·25
	Magnesia	·45	·46	·50	·51	·62	·56
3·8	Potash	3·02	2·13	2·75	3·13	4·42	4·56
	Not accounted for ...	2·00	2·94	2·30	2·38	2·65	3·31
		19·04	38·40	31·52	32·16	32·48	27·84

Bones.

Samples of the bones of animals reared on affected and unaffected areas have been submitted from time to time, and the mean of the results of the analyses are given in the following table:—

TABLE XIV.

BONES from Affected and Unaffected Areas—(average of analyses).

	Affected area.	Non-affected area.
	per cent.	per cent.
Moisture	9·47	9·82
Volatile and organic matter ...	30·92	28·79
Ash	59·61	61·39
	100·00	100·00
Lime (CaO)	27·67	28·32
Phosphoric Acid (P_2O_5)	24·37	26·23

It is of interest to note that bones from affected areas contain less lime and less phosphoric acid than do bones from non-affected areas.

Summary.

1. Soils from the affected areas contain less nitrogen, lime, potash, and phosphoric acid than do those from non-affected areas.
2. The ash of the grass from affected areas contains less lime, potash, and phosphoric acid than do those from unaffected areas.
3. The amount of mineral ingredients (lime, potash, and phosphoric acid) supplied to a cow in a full ration of grass from affected areas does not supply as much lime, potash, and phosphoric acid as is required by an ordinary healthy cow, whereas the mineral ingredients in a ration of grass from the non-affected areas do supply these.
4. Bones of animals raised on affected areas contain less lime and less phosphoric acid than do those raised on non-affected areas.

Remedial Measures.

1. The systematic manuring of pastures, with the view to increasing the mineral matter content of the grass.
2. The addition to the daily ration of the animals of ½ oz. phosphoric acid (P_2O_5), 1 oz. lime (CaO), 1¼ oz. potash (K_2O). (These quantities can be roughly supplied by the addition to the daily ration of about 2 oz. sterilized bonedust, or 1¾ oz. bone-char, together with ½ oz. slaked lime and 2¼ oz. sulphate of potash.)
3. The free use of cattle licks, made up as follow:—

   Bone-ash, 1 cwt.

   Common salt, 5 or 6 lb.

   Sulphate of iron, 4 lb.

   Molasses, sufficient to make the mass coherent and to flavour it.

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